International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD)
ISSN(P): 2249-6866; ISSN(E): 2249-7978
Vol. 5, Issue 2, Apr 2015, 1-6

INVESTIGATION ON ASTM C882 TEST PROCEDURE OF SLANT SHEAR BOND STRENGTH OF CONCRETE REPAIR MATERIAL

RASHMI R. PATTNAIK

Associate Professor, Department of ASCEE, CAET, Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha, India

ABSTRACT

The slant shear test method, ASTM C882, is widely employed test procedure to determine the bond strength of repair materials for selection of repair material for durable concrete repair. In this test procedure, the repair material is bonded to a substrate mortar specimen on a slant elliptical plane inclined at an angle 30^{o} from vertical. It assumes that the failure of the composite cylinder occurs preferentially on slant surface to calculate the bond strength. However, it was observed through experimental studies that the failure on the slant surface is not necessarily the case with all the repair materials. This paper investigates the influence of compressive strength of repair materials and substrate mortar on the failure pattern of the composite cylinders and observed that compressive strength of repair materials influence the failure pattern and bond strength of repair materials. ASTM C882 test procedure does not adequately characterize the true bond strength of the repair materials.

KEYWORDS: Concrete Repair, Repair Material, Bond Strength, Slant Shear

INTRODUCTION

The companies that market repair materials for concrete repair are the multi-national companies. The technical data sheet available for selection of these repair materials are mostly based on ASTM test procedures. Typically, the cementitious repair materials are required to meet the specification ASTM C 928 – Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs, or others developed based on individual experience of states (Austin et al.1999, Austin & Robin, 1993, Abu-Tair et al.1996, and Saldanha et al. 2013). Ideally, the selection of an appropriate repair material is a function of the type of structure, existing stress conditions at the location of the repair, environmental exposure conditions, and the time constraints placed on the repair operations. However, in practice the selection of repair material is most often based on achieving certain minimum compressive and bond strength in a short duration, so that the structure can be put into immediate service (Pattnaik & Rangaraju, 2007). The practical importance of the rapid setting and hardening behavior of repair materials is often reflected in the specifications imposed on the repair materials as seen in ASTM C928 specification.

In the ASTM C 928 specification, the bond strength between the repair material and substrate concrete is determined using the slant shear test method as specified in ASTM C 882 test procedure. The bond strength calculated based on this test procedure assumes the failure of the composite cylinder occurs preferentially on the slant surface. However, previous research studies have shown that, the failure on the slant plane is not necessarily the case with all the repair materials (Austin et al.1999, Knab & Spring, 1989, Austin et al.1995). The possible reasons for this deviation from

the expected behavior include significant differences between the compressive strength, tensile strength, modulus of elasticity and poisson's ratio of the repair and the substrate materials. In this regard, the ASTM C 882 specification does not provide adequate guidance on the compatibility of the substrate mortar specimens and the repair materials.

In this paper an experiment was conducted to investigate the influence of compressive strength of substrate mortar on the bond strength of the repair materials using ASTM C882 test procedure.

RESEARCH SIGNIFICANCE

Often the approvals of concrete repair materials are made on achieving a specified bond strength along with other parameters such as compressive strength and setting time. Slant shear test method as per ASTM C 882 standard is widely used to measure the bond strength of the repair materials. However, performance of repair materials has shown that this test method does not adequately characterize the true bond strength of the repair materials due to some inherent shortcomings. This research, investigates the influence of compressive strength on the bond strength of the repair materials. The findings from this research will help the engineers in charge of selection of repair materials for durable concrete repair.

EXPERIMENTAL TEST METHODS

Following test methods were used to investigate the slant shear bond strength verses the compressive strength of repair materials.

Slant Shear Bond Strength

The bond strength of the repair materials is determined using the standard ASTM C 882 test procedure. In this test procedure, the repair material is bonded to a substrate mortar specimen on a slant elliptical plane inclined at 30° angle from vertical to form a 76 mm x 152 mm (3-in. x 6-in) composite cylinder (see Figure 1).

Figure 1: Slant Shear Bond Strength Testing

Before the repair material was bonded to the substrate mortar, the slant surface of the substrate mortar specimen is prepared by sandblasting and dry brushing. The test was performed by determining the compressive load required to fail the composite cylinder and the bond strength was calculated as [Max Load]/ [Area of Slant Surface].

In this study, two classes of bond strength – Minimum bond strength (as calculated based on ASTM C 882) and Actual Bond Strength – are recognized for sake of clarifying the mode of failure. If the failure occurred on the slant surface, the actual bond strength is same as the minimum bond strength. However, if the failure surface is not on the interface, the bond strength as per the ASTM C 882 calculation represents minimum bond strength. In these tests,

the substrate mortar used in evaluating the bond strength is required to have a minimum compressive strength of 31 MPa (4500 psi) at 28 days of age as per ASTM C 882 test method.

Compressive Strength

The compressive strength of the repair materials and substrate mortar were determined using 50 mm (2-in) cube as per the ASTM C 109 standard practice, since the repair materials are primarily mortars. The cubes of the repair materials were tested in compression at 28 days. The cubes of the substrate mortar were tested at 35 (28days moist cure + 7 days air dry cure before casting repair materials) and 63 days (35 days + 28 days of repair materials to gain strength).

EXPERIMENTAL METHODOLOGY

In this investigation, the influences of compressive strength on the bond strength of eight different repair materials were determined by using ASTM C 882 test procedure. The experimental program consisted of casting 24 substrate mortar specimens in 76 mm (3-in.) diameter x 152mm (6-in.) tall plastic cylinder molds that were fitted with a specially designed inset to create a slant surface for bonding the repair materials. The proportions of the materials used in preparing the substrate mortar were based on a cement-to-sand mass ratio of 1:2.5 and a water-to-cement ratio of 0.45.

Effect of Differences in Compressive Strength

In order to investigate the influence of differences in compressive strength of the repair and substrate materials on the bond strength of the repair material, composite cylinder specimens were prepared as per the ASTM C 882 test method. The composite cylinders with a given repair material were prepared on the day when the substrate cylinders were 35 days old (28 days moist cured and 7 days air-cured). The composite cylinders were de-molded 24 hours after casting, and kept for moist curing. The composite cylinders were tested for bond strength as per ASTM C 882 procedure after 28 days of casting. Along with the slant shear test on composite cylinders, cubes prepared from the same batch of mortar and repair materials were tested to determine the compressive strength of the mortar and repair materials, respectively. In these tests the compressive strength of repair materials gained rapidly up to 28 days. The substrate mortar specimens cast 35 days earlier than repair materials, did not exhibit significant changes in their compressive strengths when tested alongside the repair materials. The details of these tests are provided in the results section.

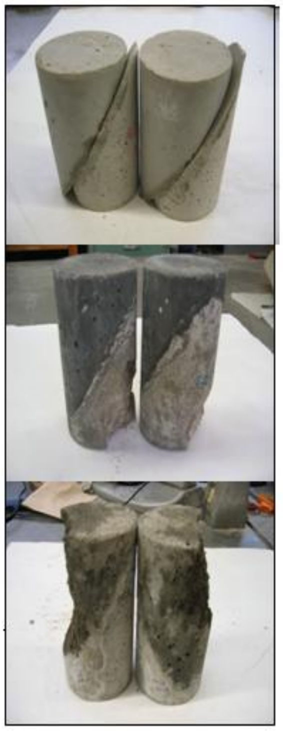
As a result of the disparity in the rate of strength gain between the repair materials and substrate mortar, the bond strength of a given repair material determined at any particular age reflected the influence of a unique combination of properties of the repair and the substrate materials. Depending on the age of testing of the composite cylinder for bond strength, the compressive strength of the repair materials were lower, similar or greater than the strength of the substrate mortar. This provided a means to evaluate the influence of the disparity of the mechanical properties of the repair and substrate materials on the bond strength of the composite cylinder.

RESULTS AND DISCUSSIONS

In the present investigation the compressive strength of the substrate mortar at 35 days was found to be 45 MPa (6,587 psi). It was observed that in the subsequent 28 days during which the composite cylinders were cured, the substrate mortar registered only an additional 6.5 MPa (985 psi) increase in compressive strength. In contrast, test specimens of repair materials cast alongside the composite cylinders exhibited a rapid gain in compressive strength, ranging from 31 MPa to 82 MPa (4,500 to 12,000 psi).

It is apparent from observing the data that depending on the specific repair material, significant difference exists between the properties of the repair material and the substrate at any given age. This disparity in strengths can be expected to influence the failure mode and the bond strength determined in the composite cylinder.

In conducting the bond tests on the repair materials, three different modes of failures were observed as shown in Figure 2. Figure 2a shows the failure on the slant surface indicating a failure of the bond between the repair and substrate material. Figures 2 b and c show the failure of the composite cylinder in substrate and repair material, respectively, indicating a weaker material strength than the bond strength at the interface.



a) Failure on slant surface

b) Failure of Substrate Mortar

c) Failure of Repair Material

Figure 2: Failures of the Composite Sections

Effect of Differences in Compressive Strength

Table 1 shows the compressive strength of substrate and repair materials, and the bond strength of the repair materials. The compressive strength of the repair material was determined at 28 days after casting the repair material specimens, while the corresponding compressive strengths of the substrate mortar were obtained at 63 days after casting the test specimens. In cases where the failure of the composite cylinder was not on the slant surface, a composite compressive strength was determined. Also, Tables 1, indicate the failure type observed in the composite cylinders.

It can be observed from the results in Tables 1 that the repair materials A, B, C and D failed in the substrate mortar because of higher compressive strength than the substrate mortar. While, repair material E failed in the repair material due to the compressive strength close to the substrate mortar. It was also observed that the failure of the composite cylinders occur on the interface, if the compressive strength of repair materials are lower than the compressive strength of the substrate mortar.

When the compressive strength ratio between repair material and substrate mortar is approximately 1.0 or less, the repair material is either similar or inferior in compressive strength compared to substrate mortar. In these situations, it

is evident from observing the data in Table 1 that the failure occurs either in the repair material or on the slant surface.

Table 1: Compressive and Slant Shear Bond Strength

Repair Material	Substrate* Comp. Strength (MPa)	Repair Material Comp. Strength (MPa)	Minimum Bond Strength (ASTM C 882)	Actual Bond Strength (MPa)	Failure Mode (Refer Figure 2)
A	50.3	73.2	21.8	-	Substrate (b)
B	49.4	73.3	21.3	-	Substrate (b)
C	53.2	69.3	21.2	-	Substrate (b)
D	52.1	64.4	21.4	-	Substrate (b)
E	54.7	50.7	15.4	-	repair material (c)
F	55.9	42.9	20.2	20.2	Slant surface (a)
G	50.4	41.9	21.1	21.1	Slant surface (a)
H	55.8	30.6	17.8	17.8	Slant surface (a)

* The Substrate compressive strength represents the average strength of the specimen from same batch of mortar used for a particular repair material.

It is well known that concrete and mortars are weak in tension. Therefore, when a compressive load is applied on a concrete or mortar cylinder the failure occurs due to the principal tensile stresses generated in an orthogonal direction to the applied stress. In a composite cylinder in which the repair material is bonded to substrate mortar on a slant surface, the applied compressive load exerts a complex state of stress on the slant surface which is dominated by shear stresses. However, a principal tensile stress is also exerted in a direction perpendicular to the applied compressive load. If the bond between the repair material and the substrate material is good to sustain the shear stresses generated on the slant surface, then the failure mode in the composite cylinder is dictated by the tensile strength corresponding to the compressive strength of the repair material. Therefore, it is observed that for a good bond strength between repair material and substrate mortar the failure occurred in the substrate mortar or on the repair material rather than at the interface. Therefore, slant shear test method as per ASTM C 882 has shown that this test method does not adequately characterize the true bond strength of the repair materials

CONCLUSIONS

Based on the results from the experimental program it can be concluded that the bond strength measured by the slant shear test method is dependent on the compressive of the repair materials and substrate mortar. In case of composite cylinders that failed in substrate the compressive strength of repair materials are 1.50 more than the compressive strength of substrate mortar. The failure occurs on slant surface when the compressive strength of the repair materials are less than the compressive strength of substrate mortar. However, the results from this investigation are limited to eight repair materials, additional data is needed to define more precisely the limits of compressive strength ratio within which a particular failure mode would occur.

REFERENCES

1. Abu-Tair, A. I, Rigden, S. R. and Burley, E. (1996). Testing the bond between repair materials and concrete substrate, *ACI Material Journal* 93 (6), pp.553–558.

2. Austin, S. A, Robins, P. J. and Pan, Y. (1999) Shear bond testing of concrete repairs, *Cement and Concrete Research*, 29, pp.1067-1076.

3. Austin, S. A. and Robins, P. J. (1993) Development of a patch test to study the behaviour of shallow concrete patch repairs, *Magazine of Concrete Research*, 45 pp. 221–229.

4. Knab, L. and Spring, C. B. (1989). Evaluation of test methods for measuring the bond strength of portland cement based repair material to concrete, *Cement, Concrete and Aggregate* 11 (1989) pp.3–14.

5. Pattnaik, R. R. and Rangaraju, P. R. (2007) Analysis of Compatibility between Repair Material and Substrate Concrete Using Simple Beam with Third Point Loading, *Journal of Materials in Civil Engineering*, ASCE, Vol. 19, No. 12, pp. 1060-1069.

6. Saldanha, R, Júlio, E, Dias-da-Costa, D. and Santos, P. (2013). A modified slant shear test designed to enforce adhesive failure, *Construction and Building Materials* 41, pp 673–680

7. Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs, ASTM C 928-00, Volume C 4.02, American Society for Testing and Materials, Philadelphia, PA (2010).

8. Standard Test Method for Bond Strength of Epoxy Resin Systems Used with Concrete, ASTM C 882-99, Vol. 4.02 American Society for Testing and Materials, Philadelphia, PA (2010).